Sensitivity Analysis of the e-READINESS Composite Indicator

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Abstract

Composite indicators are increasingly used by National and International Organisations to convey information on the status of countries in fields such as environment, economy or technological development (a review is given in Saisana and Tarantola, 2002). Composite indicators are calculated combining well-chosen sub-indicators into a single aggregated measure (the composite indicator indeed), on the basis of an underlying model of the policy domain that one wishes to measure. This is normally achieved by a weighted combination of normalised sub-indicators values.

A common problem in building composite indicators is how to properly assess the robustness of the message provided by the composite indicators to the plurality of perspectives expressed by the involved stakeholders (European Commission, 2002). The experience shows that disputes over the appropriate method of establishing weights cannot be easily resolved. Cox *et al.* (1992) summarise the difficulties that are commonly encountered when proposing weights to combine indicators to a single measure, and conclude that many published weighting schemes are either arbitrary (e.g. based upon too complex multivariate methods) or unreliable (e.g. have a little meaning to society).

A second problem, which is a part of almost all research, is the missing data. Three generic approaches for dealing with missing data are distinguished. The first one, *Case Deletion,* simply omits the missing records from the analysis. On the other hand, the other two approaches see the missing data as part of the analysis and therefore try to impute values through either *Single Imputation* (Mean/Median/Mode substitution, Regression Imputation, Expectation-Maximisation Imputation, etc) or *Multiple Imputation* (like Markov Chain Monte Carlo algorithm). This latter technique is the only one providing confidence bounds for imputed data (Rubin, 1996; Schaffer, 1997).

In the field of composite indicators development, uncertainty analysis (UA) and sensitivity analysis (SA) are too rarely employed, and when this happens, the two

types of analysis are treated separately. A synergistic use of UA and SA is proposed and presented in this work, using the e-READINESS composite indicator as case study. The e-READINESS of European enterprises, an initiative of the European Commission within the e-Europe 2005 action plan, is a composite indicator assessing the internet business environment of different countries based on the responses of enterprises to a Eurostat survey. In addition, eight additional variance-based sensitivity indices are proposed (at no extra computational cost) and compared with the existing ones (Saltelli, 2002).

The work is divided in the following steps:

1. Imputation of missing data
   The composite indicator Y_c for a given country c is a simple linear weighted function of k sub-indicators I_{ic} and k respective weights w_i, given by

$$Y_c = \sum_{i=1}^{k} I_{ic} \cdot w_i$$

   After excluding the totally missing component variables and countries, the data availability was approximately 89% for 2001 and 81% for 2002. The *Multiple Imputation* method is employed to impute several values (M) for each missing value (from the predictive distribution of the missing data).
2. Quality assessment of the imputation procedure
   The composite indicator is evaluated for the M versions of completed data sets assuming an approximate weighting configuration (fixed weights). For each country and year the mean and variance of the composite indicator is estimated. The variance due to imputation is then decomposed in '*within imputation variance*' and '*between imputation variance*' to calculate approximated confidence intervals.
3. Monte Carlo Execution
   The imputed I_{ic} and the weights are considered "uncertain factors" in the subsequent Monte Carlo – based uncertainty analysis. The statistical distribution of the imputed values is easily calculated from the M complete data sets. And the distribution of the weights is derived from the results of an expert opinion survey (budget allocation, analytic hierarchy process, or other). Thus, the output Y_c will be itself a random variable depending on the uncertain factors.
   A Monte Carlo sample of size C is generated for the uncertain factors (imputed values + weights of sub-indicators) and the composite indicator is evaluated C times for al the countries and years. Different country rankings are possible due to the underlying uncertainties.
4. Calculation of Sensitivity Indices
   Eight first order sensitivity indices (six of them new) and four total effect sensitivity indices (two of them new) are computed and compared. The additional sensitivity indices are provided at no extra computational cost. First order indices are defined as the fractional contribution to the model output variance due to the uncertainty in X_i (i.e., imputed values and weights of sub-

indicators). On the other hand, a total sensitivity index is defined as the sum of all the indices (S_i and higher orders) where X_i is included: the total index concentrates in one single term all the interactions involving X_i.

5. The Importance of the study

   Press and policy-makers like composite indicators as they help focusing policy debates. But methodological gaps in their design and construction may invite politicians to draw simplistic conclusions or the press to communicate misleading information. That is why national and international organisations believe that it is important to focus on methodological issues in the design of composite indicators.

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